Observations of Lunar Meteors by ALPO-LMIS

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Some background…

- The Association of Lunar and Planetary Observers (ALPO)
  - A Pro-Am organization that encourages the wider amateur community to make and submit scientifically useful observations of solar system objects to the organization
  - Most of the submissions are digital but there are still sections that use visual drawings (primarily for historical purposes)
  - Data are made available to the professional community for use in their research

Some background…

- The ALPO Lunar section
  - Includes three components: the Topographic Studies & Selected Areas program; the Lunar Transient Phenomena program and the Lunar Meteoritic Impact Search program
  - The Lunar Meteoritic Impact Search (LMIS) section was established in 2000 AD as a result of a successful campaign hosted by IOTA (International Occultation Timing Association) to look for lunar Leonid meteor strikes in November 1999
- The relationship between lunar meteors and Lunar Transient Phenomena (LTP)
- The First Confirmed Lunar Meteor Impact Observations, 18 November1999

The Lunar Meteoritic Impact Search (LMIS) section of ALPO

- LMIS has been active since March 2000.
- “Housed” within the Lunar Section of the Association of Lunar and Planetary Observers
  - Within the Lunar Topographic Studies section are several activities: the Bright Lunar Rays Project, the Banded Craters Program, and the Selected Areas Program (which includes the studies of lunar dome features)
  - There are also online forums for each of these sections
- In the 1950’s and 1960’s the ALPO conducted two lunar projects which each ran for several years then were canceled

The Lunar Meteoritic Impact Search (LMIS) section of ALPO

- ALPO Founder Walter Haas wrote about and attempted observations of lunar meteors in the late 1930s and early 1940s
  - He had witnessed a transient bright moving speck on the moon on July 10, 1941
  - This began the systematic search for lunar meteoritic phenomena from 1945 to 1965
- The Lunar Meteor Search Project
  - Two programs which operated from 1955 to 1965
  - Coordinated by Robert M. Adams from 1955 to 1962, then by Kenneth Chalk from 1962 to 1965

The Lunar Meteoritic Impact Search section of ALPO

- The Lunar Meteor Search project, continued
  - At its peak more than 40 observers were involved and submitted several reports
  - Unfortunately the program never achieved its goal of simultaneous, independent positive observations
  - It became clear, even before this latest project, that a single observation of a lunar meteor candidate was unreliable and needed a second, distant, simultaneous observer to confirm the event as being lunar in origin
  - Without the video capabilities enjoyed by today's astronomers, observations back then were purely visual and were very tedious to carry out

Lunar Leonids

- With the expected Leonid storms of 1999, it was realized that the moon would be passing through an especially dense ribbon of material
- David Dunham, president of IOTA (International Occultation Timing Association), organized a campaign to observe the un-illuminated crescent of the waxing gibbous moon
  - The bright sunlit hemisphere would overwhelm most of the expected faint meteor flashes
  - The dark hemisphere, still faintly lit by Earthshine, would provide both a dark background to maximize contrast and a faint image of features to provide context

Lunar Leonids

- I observed a very brief flash near the earth-lit limb of the moon: it was bright enough to be un-mistakable but brief enough to have a surreal element to it…
  - The observation was visual with a 14-inch f/11 Cassegraine, the largest of three instruments at the observatory of the Houston Astronomical Society
  - The event was confirmed the next day with Dr. Dunham's videotape of the same region
  - Five additional events were confirmed by others, mostly by video observation

Lunar Leonids

- At this time a new software was being developed to automatically detect transients, eliminating the need to manually search videotapes for the fleeting optical signatures of impact flashes
- Known as LunarScan, developed by Peter Gural, this software was tested on videotapes of the moon in search of lunar Leonids.
- The software aided in the confirmation of five event and the detection of five additional candidates.

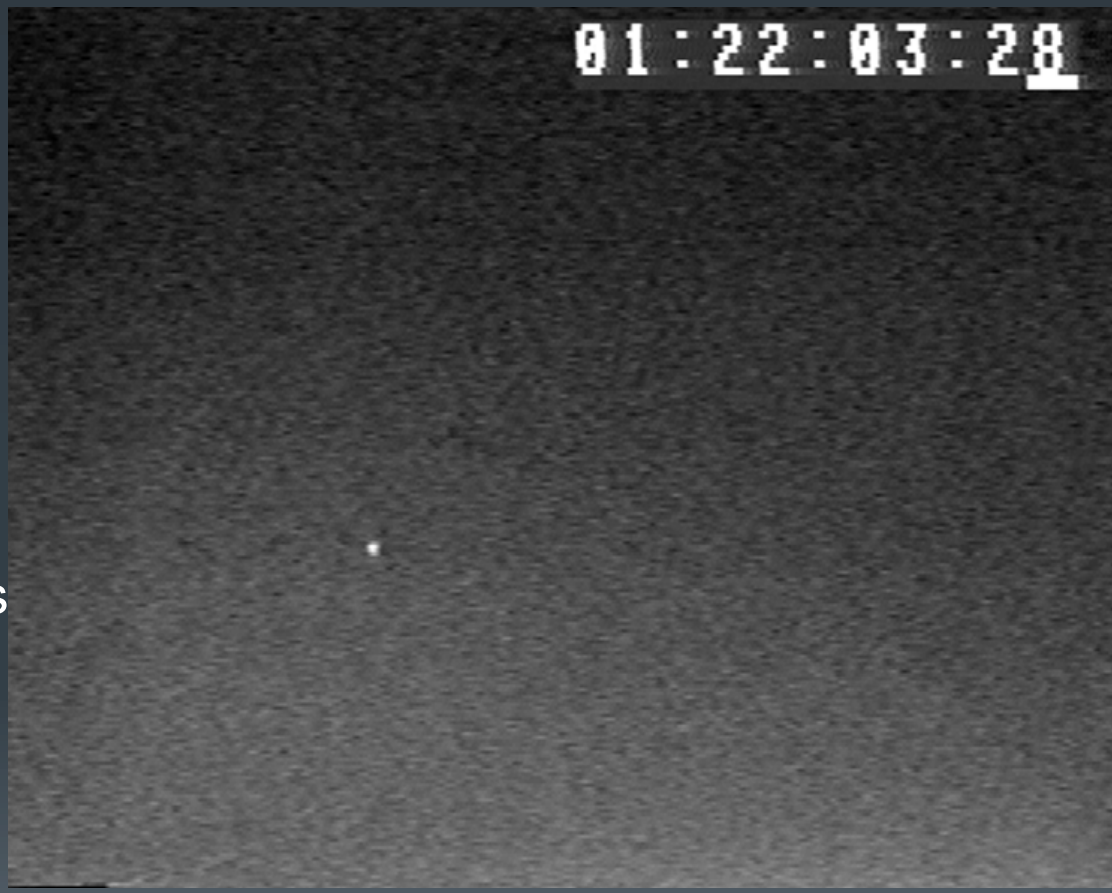


Image is a video frame from David Dunham's videotape of 1999 Leonid impact "A"

(impact video example--http://www.angelfire.com/space2/robertspellman/)

A Brief History of the ALPO-LMIS

- Establishment of the section in March 2000
- The next major outburst of the Leonids where the moon was favorably placed for observation was November 2001
  - Despite a crescent moon with most of the dark hemisphere facing Earth, only two confirmations were realized, with a number of additional candidates remaining unconfirmed.
  - A bright Earthlit background, the low elevation of the moon, and the lower numbers of meteoroids at the moon likely combined to reduce the numbers videotaped
- The first confirmed non-Leonid meteor impact was observed during the Perseids in August 2004 by a Japanese observing team (Takamura, et al.)
- Since its inception some 85 lunar meteor candidates have been reported, of which 9 were unambiguously confirmed

A Brief History of the ALPO-LMIS

- For the duration of the first decade of the 21st century, the focus of the project was on major annual showers when the moon was favorably placed
- During this time I assembled and published with Springer a book entitled “Lunar Meteoroid Impacts and How to Observe Them” in 2009.
- The Meteoroid Environment Office at NASA-Marshall Space Flight Center (Huntsville, Alabama, USA) began an observing program in the fall 2005 and has since made observations of 299 provisionally verified impacts.
- ALPO LMIS also participated in the observations of two artificial impacts: SMART-1 in September 2006 and LCROSS in October 2009.

Typical Activity of the ALPO-LMIS

- As already mentioned the primary focus of ALPO-LMIS has been the more significant annual meteor showers
  - Showers are selected with a ZHR of at least 15 and with the Moon favorably placed for ground based observations of lunar meteors
  - “Favorably placed” means that a significant fraction of the unlit moon is visible from Earth
  - This typically happens during the waxing crescent phase (most favorable) and the waning crescent phase (less favorable but still useful)
  - The ZHR threshold is selected to maximize the use of observers’ valuable time and thus to maximize the chance of a positive detection
- The section has also served as a place for observers to report sporadic observations which are shared via the Web in hopes of getting confirming observations
- More recently we have moved to a monthly observing format where the moon is observed as continuously as possible, inside and outside of shower activity, for meteoroid impacts.

Typical Activity of the ALPO-LMIS

- The monthly campaign had been attempted several times in the last decade but have not been sustained due to the time intensive nature of such a campaign
- However, with the launch of LADEE there is renewed interest in monitoring the moon more regularly each month
  - We mirror the observing plan of NASA-MSFC-MEO lunar impact monitoring program
  - We begin each month with the waxing crescent Moon three to four days after New and continue until one to three days past First Quarter
  - The actual arc of observing time depends on the moon's elevation / ecliptic angle and the ability of observers to eliminate stray light from the waxing moon
  - We resume one to three days prior to Last Quarter and continue until three to four days before New.
- We began this routine in June 2013 and will continue for the foreseeable future

17 March 2013-The Brightest Impact Flash Yet Observed

- A bit of excitement earlier this year with some unexpected visits by some unexpected objects.
- At 3:50:55UT on 17 March 2013 at lunar latitude 20.6N, longitude 23.8W, an explosion the equivalent of that produced by 5 tons of TNT was observed from a quarter million miles away.
- That same night, from Earth, at least five bright fireballs were observed by all-sky cameras in Georgia and SE Canada.
- (Images next two frames courtesy of NASA)


20130317 06:41:45.498620 UTC (4)
Yarker (10A)

17 March 2013-The Brightest Impact Flash Yet Observed

- All six objects were found to travel together in highly eccentric orbits, with semi-major axes of around 2.25AU, extending out to the inner asteroid belt
- The object that hit the moon was calculated by William Cooke to have the size of a beach ball (35 cm across) and impacted at 57,000 mph (25.6 km/ sec.)
- The resultant crater is thought to be approximately 20 feet (6 m) across.
- The objects may be part of a little-known shower known as the eta-Virginid (or North March Virginid) meteor shower (we will be watching next year…)

The process of watching for and pinpointing impacts

- Prior to the days of video, this type of work was exhausting and frustrating to the visual observer (but it can be done…)
- For this very reason, video setups are the preferred approach to monitoring the moon
- Setups can come in many variations from static to portable but each typically includes the following components: a telescope, a low-light video camera, a time insertion device, and a recording device.
- The next image shows a portable setup geared toward occultation work, this one belonging to Houston astronomer Richard Nugent

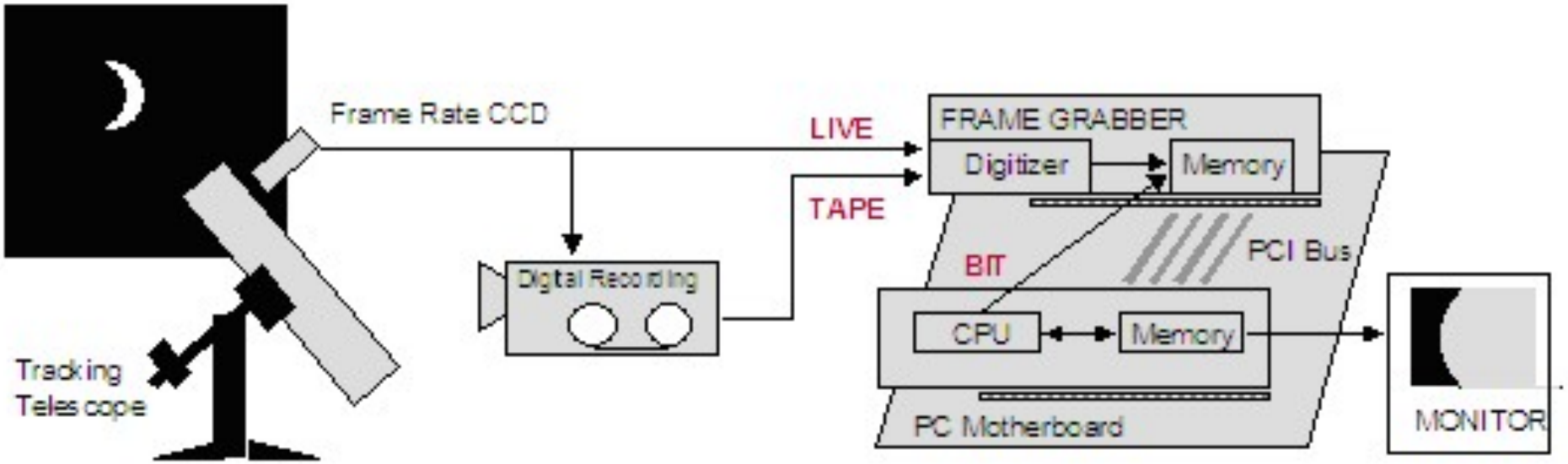

SHARP
32x
Energizer

The process of watching for and pinpointing impacts

- For typical lunar meteor video work, a telescope of short focal length in the 8 to 14-inch aperture range is ideal
- The telescope needs to track at lunar rate and be on an equatorial mount or incorporate a de-rotator
- An astronomical video camera for low-light applications (e.g. Watec 902 or PC 164 C from Supercircuits) is needed to capture the video
- A time encoder or signal is essential and can range from a clear audio signal from radio station WWV or CHU; but preferably a GPS-based video time inserter is needed
- Mr. Varros and Mr. Suggs will provide more of the technical details in their talks…

Automated impact detection

- The basic idea of automated impact detection is summarized in the sketch-up shown below
- The software of choice is a program called LunarScan 1.5 by Pete Gural
- George Varros also offers a program for precision guiding at lunar rate (called “Nudger”, at www.lunarimpacts.com)

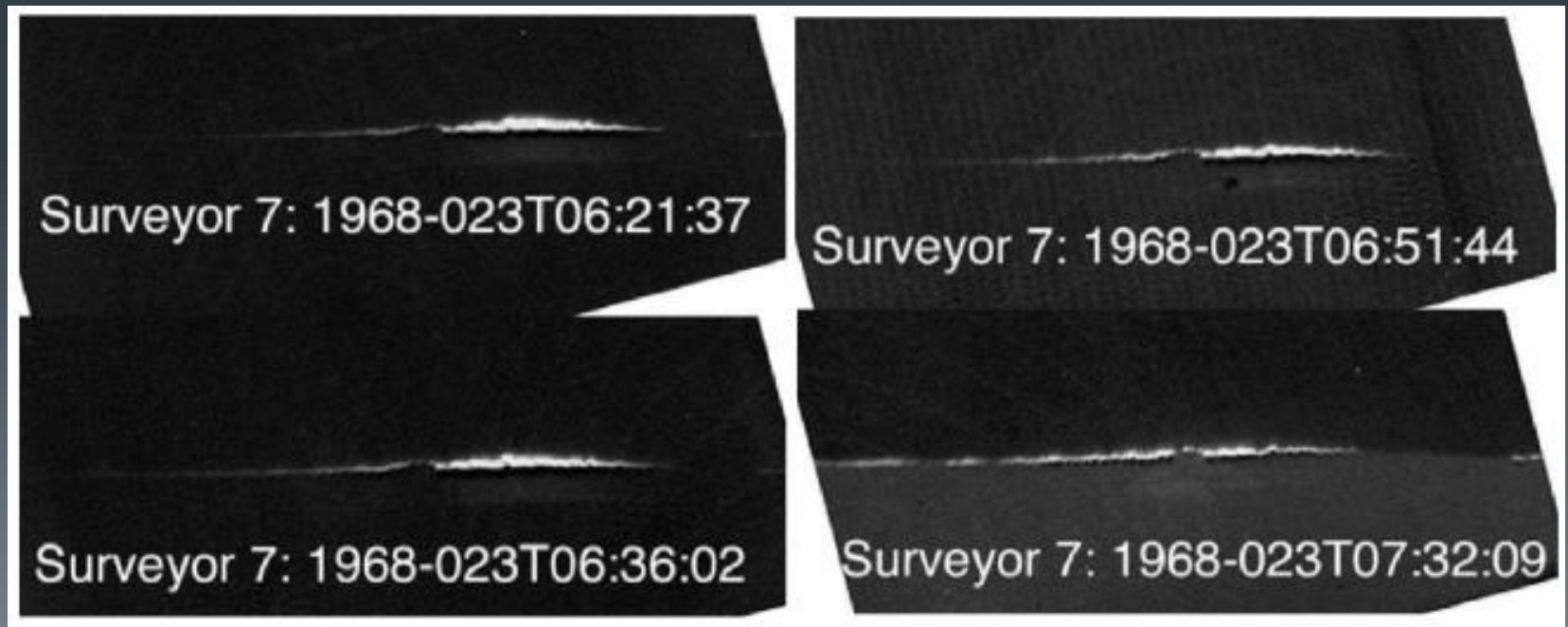


Confirming Impact Events

- Once an event is spotted an accurate measure of its selenographic position as well as the time of the impact (to the nearest second) is needed
  - **Software such as the Virtual Lunar Atlas is helpful in pinpointing the location of a putative impact event**
  - **It is vital that a second observer, at least 30 km distant, be observing at the same time and with similar instrumentation to provide confirmation for an event**
  - **It is possible to get a tentative confirmation by two equal setups less than 30 km apart but the uncertainty of the quality does go up a bit**
  - **For the latter situation, cosmic ray incidents can be ruled out if an event were recorded simultaneously with the two setups**

LunarImpacts@yahoogroups.com

- This is the online forum used to communicate all things dealing with lunar meteors
- One can link to this through the ALPO website or through the yahoogroups website. Membership requires moderator (my) approval but it is usually not a problem, especially if you include a brief description of yourself and your interests



The Lunar Impact Online Discussion group, cont'd

- We have used the yahoo-group list serv/discussion groups to share a number of topics of interest to this type of astronomy:
  - Requests for confirmation of lunar meteor impact candidates
  - Announcements of upcoming opportunities and reminders as these opportunities get closer
  - Discussion of technologies and techniques used in the observations of lunar meteors
  - Assistance for those in need of help to solve a problem with software or to choose the best approach to set up an observing system (or help with their existing observing system)
  - And much, much more!
- This forum will be a useful tool for the ongoing observing campaign in support of LADEE science

LM Obs. @ PVAMU

- As part of a grant awarded by the Title III program of the Department of Education, we are expanding our astronomical influence within the Physics department at Prairie View A&M University (PVAMU)
- PVAMU, a part of the Texas A&M System of Universities, is a Historically Black University (HBCU) who serves a diverse population of students

LM Obs. @ PVAMU

- We currently have 16 physics majors in various stages of their matriculation (two of which are about to graduate)
- One of the main purposes of our Title III grant is to provide these majors with another option for senior project research in the form of astronomical observations
- One such project involves video monitoring of the moon for meteoroid impacts.

Lunar Meteor Observations @ PVAMU

- In addition to our science majors, education majors studying to be science teachers at the middle and high school levels can also benefit from this program
- These students may participate in our observing program in conjunction with an existing class or lab, or as a special topics course
- We also will be collaborating with other groups such as IOTA and NASA, and will be continuing our promotion of professional-amateur collaboration through events such as the annual Lunar and Planetary Science Conference
- The general public will also be invited through this “citizen-science” activity

The Next Steps…

- We are currently assembling our observing setup for monitoring lunar meteor phenomena
- We just received two laptops equipped with FireWire for capture and digitization of data
- We will use an existing 8-inch Celestron with f/3.3 focal reducer and PC 135 low light video camera with KIWI-OSD GPS time stamp for observations

Image courtesy of Saganti, et al.

The Next Steps…

- Plans are to upgrade to a larger telescope in the early part of 2014 and to purchase additional cameras and external hard drives to complete the upgrade
- Observation activities will continue beyond the period of the LADEE science mission and will be integrated into the overall scheme of ALPO-LMIS

Image courtesy of Saganti, et al.

In Conclusion

- Not only will we be working with PVAMU but we will also continue to accept contributions from interested individuals and organizations willing to assist in this endeavor
- It is hoped that we will be able to, at PVAMU acquire a means of doing spectrophotometry on some of the brighter impact flashes
- We also hope to enable our physics students to acquire the data needed to submit a publication to a science conference or journal